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SATURN, 1901.

Corrections to Le Verrier's Tables.

Day. 1901.		R.A.		Dec.	Day. 1901.		R.A.		Dec.
		Time.	Arc.				Time.	Arc.	
		s	"	"			s	"	"
Jan.	2	−·24	−3·3	+0·4	July	5	−·30	−4·2	+0·2
	10	−·25	−3·5	+0·2		13	−·29	−4·0	+0·2
	18	−·25	−3·5	+0·2		21	−·27	−3·8	+0·4
	26	−·28	−3·9	+0·2		29	−·25	−3·5	+0·3
Feb.	3	−·29	−4·0	+0·1	Aug.	6	−·24	−3·3	+0·2
	11	−·30	−4·2	+0·1		14	−·24	−3·3	+0·4
	19	−·32	−4·5	0·0		22	−·23	−3·2	+0·3
	27	−·31	−4·3	+0·1		30	−·22	−3·0	+0·3
Mar.	7	−·31	−4·3	+0·1	Sept.	7	−·20	−2·8	+0·5
	15	−·35	−4·9	0·0		15	−·19	−2·6	+0·4
	23	−·35	−4·9	0·0		23	−·19	−2·6	+0·3
	31	−·34	−4·7	+0·1	Oct.	1	−·18	−2·5	+0·5
April	8	−·36	−5·0	0·0		9	−·19	−2·6	+0·5
	16	−·35	−4·9	0·0		17	−·17	−2·3	+0·4
	24	−·35	−4·9	+0·1		25	−·19	−2·6	+0·1
May	2	−·35	−4·9	0·0	Nov.	2	−·21	−2·9	+0·3
	10	−·34	−4·7	−0·1		10	−·19	−2·6	+0·3
	18	−·34	−4·7	+0·1		18	−·19	−2·6	+0·2
	26	−·32	−4·5	0·0		26	−·20	−2·8	+0·2
June	3	−·34	−4·7	+0·1	Dec.	4	−·20	−2·8	+0·2
	11	−·33	−4·6	+0·1		12	−·22	−3·1	0·0
	19	−·30	−4·2	+0·1		20	−·21	−2·9	0·0
	27	−·30	−4·2	+0·1		28	−·22	−3·1	+0·1

Note on the Geographical Position of the University Observatory, Oxford. By A. J. Walker, M.A.

[Introductory note by H. H. Turner, Savilian Professor.—Since my appointment at the end of 1893 the Astronomical work of the Observatory has been that of the Astrographic Chart, and no precise determination of the position has been required. It has been realised, however, that the accepted position is defective, and as soon as opportunity offers a more exact determination will be made. Meanwhile the following statement by Mr. Walker summarises the available information. I am much

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obliged to him for the time and trouble he has expended in making these measurements.—H. H. T.—1899 August.]

In *Astronomical Observations made at the University Observatory, Oxford*, No. 1 (published in 1878), at p. vi of the introduction will be found the following statement: "The geographical position of the Observatory, as given in a communication from the Ordnance Survey Department, under the direction of Col. Sir H. James, is as follows :—

Longitude West of Greenwich	1° 15′ 5″·991
North Latitude	51° 45′ 34″·152."

This is the position which has appeared in the *Nautical Almanac* ever since, the longitude of course being expressed in time—$5^{m}\ 0^{s}\cdot4$ west. The *Almanac* for 1898 gives as the source of its information Lancaster's *Liste General*. This was the first year that the *Almanac* contained the source from which the positions of observatories were derived.

In 1897 some Z.D. observations made with the Barclay Transit Circle of the University Observatory exhibited considerable discordances. In recording these observations Prof. Turner wrote : "These discordances could not be attributed to any known cause. Later it was found that the O.G. was possibly loose (see collimation observations). But the matter requires clearing up. The assumed latitude is possibly to some extent in error, though this cannot explain the whole discordances. From differential observations on the Radcliffe Observatory it would appear that the latitude should be 1″ or 2″ smaller."

Unfortunately the communication from the Ordnance Survey Department does not seem to have been preserved ; at any rate, it cannot now be found. There is, however, among the records of the Observatory a paper purporting to show the orientation of the building, and stating that the orientation is 5 inches out in the length of the building. This was apparently communicated by the Ordnance Survey Department.

The position of the University Observatory, carefully taken from the 6-inch Ordnance Map (R.F. $\frac{1}{10560}$), is :—

Longitude 1° 15′ 6″·6 or $5^{m}\ 0^{s}\cdot5$ W. Latitude 51° 45′ 33″·8 N.,

or 0″·6 ($0^{s}\cdot1$ nearly) = 37·7 feet further west and 0″·4 = 40·6 feet further south than the position furnished by the Survey Department. But it would not be difficult to make an error of 0″·2 in taking off the position, and it is difficult to exactly define the point on the map which represents the position of the Transit Circle.

But the position of the University Observatory may be

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obtained in another way. Its bearing and distance from the Radcliffe Observatory may be determined, and the difference of latitude and longitude so obtained may be applied to the received position of the latter Observatory. There is, however, apparently no record of this having been done till 1897. Certain differential observations made in that year have already been mentioned. Measurements have now been made upon the 25-inch Ordnance Map (R.F. $\frac{1}{2500}$), and from these the University Observatory would appear to be 358 feet to the south and 2,425 feet to the west (true) of the Radcliffe Observatory. The first of these distances is equivalent to a difference of latitude of $3''\cdot5$, while the second corresponds to a difference of longitude of $38''\cdot5$ or $2^{s}\cdot6$. If we take the position of the Radcliffe Observatory from the N.A. for 1898 we have :—

	Longitude.		Latitude.		
	m	s	°	′	″
Position of Radcliffe O. from N.A.	5	2·6 W.	51	45	35·4 N.
Diff. Long. and Lat. from Map		−2·6			−3·5
Resulting position of U.O.O.	5	0·0 W.	51	45	31·9 N.
Position of U.O.O. from N.A.	5	0·4 W.	51	45	34·2 N.
Difference		0·4 = 377 feet			2·3 = 233 feet

If the relative position of the two Observatories be correctly laid down on the 25-inch Ordnance Map, it follows that the position of the University Observatory furnished by the Ordnance Survey Department differs considerably from that obtained by astronomical observations, unless indeed a large error has been made in taking the measurements from the map.

Apart from any mere inaccuracy in writing down the result of the measurements, the scale of the 25-inch map is such that a greater error than 5 feet should not be possible in taking off a distance, but it is of course not very easy to say which are the points on the map which represent the position of the Transit Circles of the two Observatories.

A measurement of the difference of latitude on the 6-foot map gave 352 feet—a difference of 6 feet from that obtained from the 25-inch map.

It now remains to check the distance between the two Observatories obtained from measurement upon the Ordnance Map, and to consider with what accuracy the position of the Radcliffe Observatory given in the *Nautical Almanac* has been determined. The second question will be first considered.

From the *Radcliffe Observations* some information can be obtained as to the determination of the position of the Observatory. In the 1841 volume (published 1843) we find the following, p. xv : " In all interpolations from the *Nautical Almanac*, the longitude of the Observatory has been considered $5^{m}\ 2^{s}\cdot6$ W. of Greenwich, which is the result of a most careful Chronometrical

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determination in the course of 1842 by the Rev. Richard Sheepshanks, the details of which I hope will be soon published." They were apparently not published in the Radcliffe Volumes, and nothing regarding them has been found in either the *Philosophical Transactions*, the *Proceedings* of the Royal Society or the *Monthly Notices* or *Memoirs* of the Royal Astronomical Society. Mr. Sheepshanks died in 1855. See memoir in *Proceedings Royal Society*, where various longitude determinations carried out by him in 1843 and one or two other years are mentioned, but none in 1842.

The longitude has also been obtained by observations of the Moon's R.A. at Oxford and Greenwich from 1864 to 1868 inclusive, and in the 1868 volume of *Radcliffe Observations* we read, p. xxxv: "The most probable result is $5^{m}\ 3^{s}{\cdot}66$ W., and this is in excess of the received longitude by $1^{s}{\cdot}06$. It must not, however, be assumed that the latter is erroneous to that amount . . ."

It would seem as if preparations were at one time made for a telegraphic determination of the longitude. It is said that a wire was laid from the Observatory to the Great Western Railway telegraph system. People now living have seen the wire dug up in the Observatory grounds and in the streets. There is also an old chronograph in the Library, which seems to point to preparations for a telegraphic determination, but no reference to the matter has been found in the annual volumes, and nothing is known about it by the present staff of the Observatory.

In 1840 the latitude adopted was $51^{\circ}\ 45'\ 36''{\cdot}0$, and this appeared as the latitude in the *Nautical Almanac* for a long time—in fact, until the present value was substituted in 1898. In 1880 $51^{\circ}\ 45'\ 35''{\cdot}16$ was adopted, and used up to 1888. In the 1888–1889 volume, we find the following remarks, p. xiv: "The assumed position of the Transit Circle of the Observatory employed in the reductions has been

Longitude	$5^{m}\ 2^{s}{\cdot}6$	West of Greenwich.
Latitude	$51^{\circ}\ 45'\ 35''{\cdot}16$	North.

The latitude used in these reductions is that which has been adopted in the Annual Volumes since 1880, but is not that which is adopted in the General Catalogue of Stars for 1890, which is $51^{\circ}\ 45'\ 35''{\cdot}39$."

It may here be remarked that the Carrington Transit Circle was brought into use in 1862, having been mounted in exactly the same position as the old Transit. Previous to the erection of the Transit Circle the observations from which the values of the latitude were obtained were made with the Mural Circle. The values of the latitude obtained from observations made in various years have been taken from the Annual Volumes, and are given on next page.

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Year.	Latitude.		
	° ′ ″		
1840	51 45 35·85		
1841	35·97		
1842	35·70		
1843	35·82		
1854	35·31		
1861	35·88		
1862	35·85		
1863	35·73		
1864	35·50		
1865	35·28		
1880	35·17	with a weight of	53·6
1881	34·95		76·7
1882	35·24		111·5
1883	35·23		55·6
1884	35·49		29·5
1885	35·43		25·1
1886	35·67		5·1
1887	35·73		19·9

For further information regarding the value adopted for the 1890 Catalogue see the introduction to the Catalogue.

In order to check the measurements taken from the 25-inch Ordnance Map, the following measurements were made on the ground in 1899 May.

On May 18 a line was set out northwards towards the cricket pavilion with the Barclay Transit Circle for a distance of 575 feet, trees preventing its being carried any further. The line was first set out with ranging rods, it being possible to see these pretty distinctly with the Transit Circle when a piece of cardboard with a small hole in it was placed in front of the O.G. The rods were then replaced by pegs into which copper tacks were driven for the purpose of more accurately defining the line.

Then, by means of a right-angled prism, the point was found in the meridian line in which that line was cut at right angles by a line from the centre of the globe on the top of the tower of the Radcliffe Observatory. The distance from this point to the Barclay Circle was found by the tape to be 359 feet, differing but 1 foot from the distance as measured on the 25-inch Ordnance Map.

The distance was then measured between two points on the meridian line from both of which the Radcliffe Observatory was visible. The mean of two measurements (which differed by ½ inch) with a 100-foot steel tape gave 334 feet 0¼ inch. The angle formed at each end of this base with the globe on the Radcliffe

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tower was then measured several times on different days with a 5-inch theodolite by Messrs. T. Cooke & Sons, of York.

The distance between the centre of the Radcliffe hall (which is assumed to be directly below the centre of the globe) and the Radcliffe Transit Circle was measured with a steel tape and found to be 44·62 feet.

As a further check, two traverses were made with the 5-inch theodolite and Chesterman 100-foot steel tape between the two Observatories, and by the kindness of the Radcliffe Observer it was possible to carry them right up to the Radcliffe Transit Circle. Owing to bad weather and difficulties caused by traffic, these measurements were made on different days and at different times of day. Every line was measured twice when possible. In most cases the back station was observed first, the theodolite being first set to zero. The compass was used as a check in the first traverse, and showed the presence of a good deal of local attraction. Details of the measurements follow :—

Summary of Results of Measurements.

	Difference of Latitude. Feet.	Departure. Feet.	
	357·65	2419·47	1st Traverse
	358·95	2418·67	2nd „
	356·47	2417·92	1st Triangulation
	356·64	2419·02	2nd „
	4 / 29·71	35·08	
Mean	357·43	2418·77	
	357·43	2418·77	From the various measurements.
	358·00	2425·00	From the 25-inch map.
	352·00		„ „ 10-foot „

Taking the difference of latitude as 357·43 feet and the departure as 2418·77 feet, and the value of $1''$ of latitude as 101·38 feet and $1''$ of longitude as 62·92 feet, we have :—

Difference of Latitude $3''\cdot53$. Difference of Longitude $38''\cdot44 = 2^{s}\cdot56$.

Distance 2445·0 feet. Bearing N. 81° 35′ 40″ W.

Hence the University Observatory is :

$3''\cdot53$ South of the Radcliffe Observatory

$\left.\begin{array}{l}\text{and } 38''\cdot44\\ \text{or } 2^{s}\cdot56\end{array}\right\}$ East „ „ „

while the Radcliffe Observatory bears from it N. 81° 35′ 40″ W. true, distant 2445 feet.

The measurements actually made on the ground agree, therefore, closely with those made on the 25-inch Ordnance Map, and

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give what is practically precisely the same difference of latitude and longitude.

The difference between the position of the University Observatory obtained by applying this difference of latitude and longitude to the N.A. position of the Radcliffe Observatory and the position furnished by the Ordnance Survey Department is, then, $0^s{\cdot}4$ in longitude and $2''{\cdot}3$ in latitude.

On 1899 July 18 a letter was written to the Director-General of the Ordnance Survey, giving the same details substantially as those here given, and asking for information on the subject. This letter was acknowledged by return of post, and a reply, dated 1899 August 2, subsequently received. This reply is appended.

Ordnance Survey Office,
Southampton, 1899 August 2.

Dear Sir,—The question raised in your letter of 18th ultimo has been investigated. Unfortunately, the data on which Sir H. James reported the latitude and longitude of the University Observatory, Oxford, cannot be found.

The positions of the University and Radcliffe Observatories as shown on our maps have been checked, and there seems no doubt as to their correctness; but the only satisfactory way of clearing up the discrepancies would be to connect the Observatories with the triangulation of the Ordnance Survey. This would take some time and entail some expense, and could not be undertaken without the sanction of the Board of Agriculture.

Yours faithfully,
Duncan A. Johnston, Colonel.

A. J. Walker, Esq.

The reply would seem to carry the matter very little, if any, further. Information was asked as to the difference between positions in or near Oxford as determined by geodetic operations and astronomical observations, but none is given. One would not naturally expect a large deflection of the vertical in Oxford. Clarke, however, remarks in his *Geodesy*, 1880, at p. 287, "The discordances resulted from the fact with which we are now familiar, that the observed latitude of any station, although from its surroundings it may be apparently quite free from any suspicion of local attraction, is yet liable to an error of one or two seconds. This amount is, indeed, often exceeded, and it is not very uncommon to find, as in the vicinity of Edinburgh, a deflection of gravity to the extent of 5" . . ." Gillespie also remarks (*Higher Surveying*, 1897, at p. 196), "An examination of the local deflection of the vertical (plumb line) at latitude stations shows that the determination of astronomic latitude with an accuracy of about a quarter of a second is quite sufficient for most schemes of triangulation, being considerably within the limits of the ordinary deflections. A greater precision is necessary in locating state and national boundaries and determining arcs."

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Variation of latitude, the range of which is apparently between 0″·2 and 0″·7, would not go far towards explaining a discrepancy of 2″·3.

On the Optical Distortion of a Doublet Lens. By Captain E. H. Hills, R.E.

In the May number of *Monthly Notices*, Professor Turner has discussed the distortion of a doublet lens, and has shown that it is at all events probable that it is a negligible quantity over a field of 11° square.

In my investigation on the determination of longitudes by photography (*Memoirs R.A.S.* vol. liii.), it was necessary to satisfy myself, before applying the formulæ of reduction to the star places, that any possible optical distortion of the lens employed did not introduce a measurable factor into the results, and I accordingly carried out some experiments on this point.

The results I arrived at were practically identical with those reached by Professor Turner, but as I approached the subject by a different road it seems desirable to give a short account of the work. The method used was to set up the camera in a fixed position, and, leaving the lens open for a considerable time, a number of star trails were drawn across the plate. The curvature of these trails was then measured and compared with the calculated amount.

For convenience of computation, the camera was so arranged that the projection of the equator fell near the centre of the plate. This is not absolutely necessary, as the rigorous formulæ present no special difficulty; but, as will be seen immediately, the employment of a simple, approximate formula for the curvature does not introduce any appreciable error until the centre of the plate is moved many degrees from the equator.

The theoretical curvature of a star trail on the plate may be derived as follows:

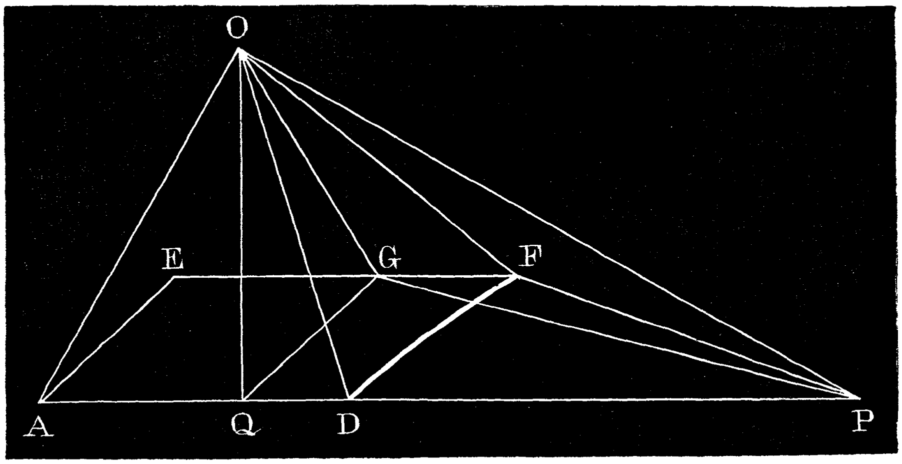

Fig. 1.